Monitoring Great Lakes Ice Cover with Satellite Synthetic Aperture Radar (SAR)

G. A. LESHKEVICH[1]   S. V. NGHIEM[2]   R. KWOK[2]

[1]Great Lakes Environmental Research Laboratory
National Oceanic and Atmospheric Administration
2205 Commonwealth Blvd., Ann Arbor, Michigan 48105, U.S.A.
Tel: 734-741-2265, Fax: 734-741-2055, E-mail:leshkevich@glerl.noaa.gov

[2]Jet Propulsion Laboratory, California Institute of Technology, MS 300-235
4800 Oak Grove Drive, Pasadena, California 91109, U.S.A.
Tel: 818-354-2982, Fax: 818-393-3077, E-mail: nghiem@solar.jpl.nasa.gov

Abstract- During the 1997 winter season, shipborne polarimetric backscatter measurements of Great Lakes ice types using the Jet Propulsion Laboratory (JPL) C-band scatterometer, together with surface-based ice physical characterization measurements and environmental parameters were acquired concurrently with RADARSAT and ERS-2 SAR data. Using a supervised classification algorithm, measured backscatter values (converted to dB) for three ice types and calm water were applied to an 8 x 8 pixel averaged ERS-2 calibrated SAR image. Certain assumptions were made on the local incidence angle, one of which was that any change in incidence angle across a distributed target was neglected, i.e. a distributed target corresponds to one average value of the incidence angle (23 $^{\circ}$ was used). Although the calculated overall uncertainty was about +/- 1 dB as a result of the averaging and incidence angle effect, an algorithm to correct for power loss and local incidence angle effect is applied in this study to the ERS-2 image, resulting in a more accurate classification.

INTRODUCTION

In previous studies, using airborne and shipborne data as "ground truth", preliminary computer analysis of ERS-1 and RADARSAT ScanSAR narrow images of the Great Lakes using a supervised (level slicing) classification technique [1] indicated that different ice types in the ice cover could be identified and mapped [2,3]. During the 1997 winter season, shipborne polarimetric backscatter data were acquired using the Jet Propulsion Laboratory (JPL) C-band scatterometer, together with aerial reconnaissance data, surface-based ice physical characterization measurements, and environmental parameters, concurrently with RADARSAT and ERS-2 overpass. The scatterometer data set, composed of over 20 ice types or variations measured at incident angles from 0° to 60° for all polarizations, was processed to radar cross-section and established a library of signatures (look-up table) for different ice types to be used in the machine classification of calibrated satellite SAR data [4].

METHODS

ERS-2 SAR imagery of Lake Superior taken during the 1997 winter experiment was used for this study. A scene of the central portion of Lake Superior collected on 22 March 1997 was calibrated and linear σ° values converted to dB according to the simplified equation for the derivation of σ° in Precision Image (PRI) products [5]. Certain assumptions on the local incidence angle were made:

- A flat terrain is considered , i.e. there is no slope. The incidence angle depends only on the earth ellipsoid and varies from about 19.5 $^{\circ}$ at near range to about 26.5 $^{\circ}$ at far range (23 $^{\circ}$ was used).
- Any change in incidence angle across a distributed target is neglected, i.e. a distributed target corresponds to one average value of the incidence angle.

Measured backscatter values (converted to dB) for 3 ice types and calm water collected with the JPL C-band scatterometer on March 21, 22, and 23 were used as test "training sets" to classify the scene. We assume that the values for the 21 and 23 of March did not change significantly from 22 March as there was no significant change in temperature or precipitation conditions. We feel the assumption is valid as values measured on 23 March for a similar ice type measured on 22 March were very comparable.

The measured backscatter values for rough consolidated ice floes, brash ice, patchy snow cover on snow ice covered black ice [6], and calm open water were applied to the 8 x 8 pixel averaged digital ERS-2 SAR image [7]. The averaging not only reduced the speckle, but resulted in an image similar in resolution to operationally used RADARSAT ScanSAR Wide images. The overall uncertainty is about +/- 1 dB.

However, for accurate derivation of geophysical parameters from the normalized radar cross section (NRCS) of ERS-1 and ERS-2 SAR data, the NRCS has to be calibrated as

accurately as possible. A problem with saturation within the analog to digital converter (ADC) of the ERS-1 and ERS-2 SARs leads to a power loss resulting in an underestimation of the NRCS. It has been determined that the highest power loss occurs over inland ice and in the near range of ocean surface images [5]. To correct for power loss, the ERS-2 image (22 March 1997) was recalibrated as described in [8] using the programs *getit* and *calit* [9]. In addition, to account for the effects of local incidence angle, the measured (calibrated) backscatter values for the three ice types and calm open water used as "training data" were interpolated every $0.5°$ between incident angles $19.5°$ and $26.5°$. These "training data" sets were then used to classify the 8 x 8 pixel averaged recalibrated image.

RESULTS AND DISCUSSION

Fig. 1 shows the color-coded result of the (level slicing) classification of the image using the calibration algorithm described in [5] Most of the ice cover in the scene was classified as rough consolidated ice floes (yellow) or brash ice (red). Areas classified as patchy snow cover on snow ice covered black ice (green) are scattered throughout the ice cover, but no calm open water was classified in the scene. Black and gray represent unclassified areas. The land area (Keweenaw Peninsula which can be masked out) was classified largely as brash ice (red) owing to similar backscatter intensity from the forested area. Fig. 2 shows the color -coded result of the classification of the image using the calibration algorithm for power loss and the correction for local incidence angle effect. As there were rather low power loss corrections to perform in this image, the results are similar to those described above. Two notable differences are that 1) there is more area classified as patchy snow cover on snow ice covered black ice (green), and 2) a small area of open water (blue) is classified in this image as the result of the more accurate calibration and "training data" sets.

Our route across Lake Superior passed through the northwest portion of the scene. The area of open water adjacent to the Keweenaw Peninsula appears reasonable as there is a strong current (Keweenaw Current) in this area, although no ground truth was collected there. Classification can be improved by inclusion of additional ice types in the training data set. Further validation needs to be done, however, this study demonstrates the capability of classifying Great Lakes ice types in calibrated satellite SAR imagery using backscatter values measured from different ice types as "training data."

ACKNOWLEDGMENTS

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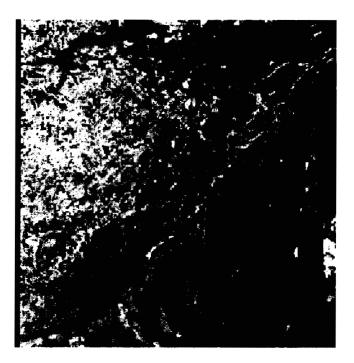
Figure 1. Classified ERS-2 scene (22 March 1997) using measured backscatter values for rough consolidated ice floes (yellow), brash Ice (red), patchy snow cover on snow ice covered black Ice (green), and calm water (blue). No calm water classified in this scene.
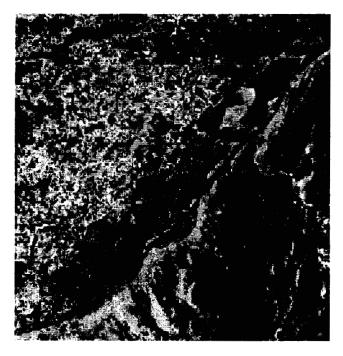

Figure 2. Classified ERS-2 scene (corrected for power loss) using the same three ice types and calm water as in Figure 1, but corrected for local incidence angle effect. Calm water (blue) is classified in this scene.